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USER'S MANUAL FOR A FORTRAN IV COMPUTER PROGRAM FOR CALCULATING--ETC(U)
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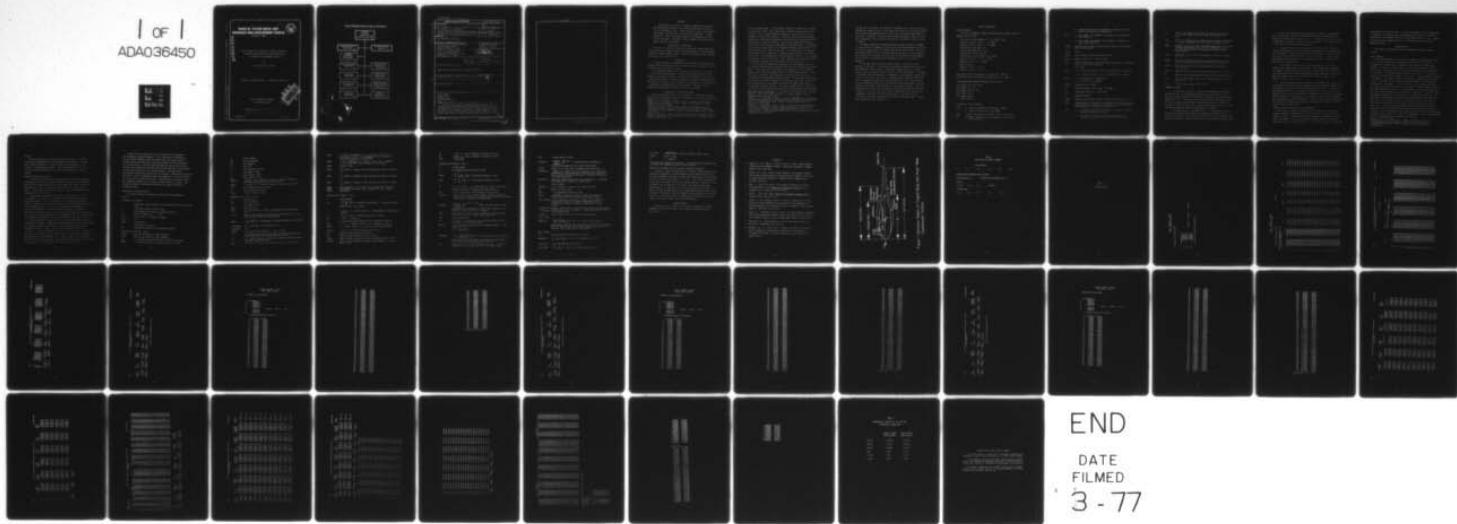
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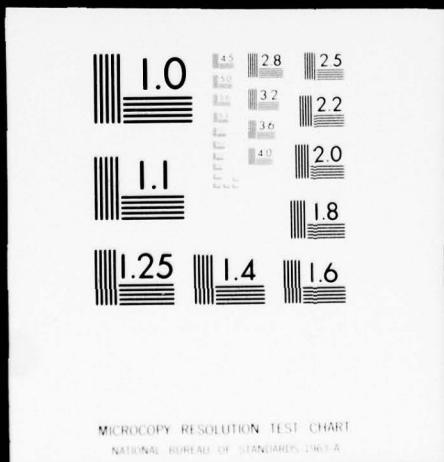
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DAVID W. TAYLOR NAVAL SHIP
# RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md.   20084

USER'S MANUAL FOR A FORTRAN IV COMPUTER PROGRAM FOR

CALCULATING THE POTENTIAL FLOW/BOUNDARY LAYER

INTERACTION ON AXISYMMETRIC BODIES

by

H.T. Wang and T.T. Huang

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

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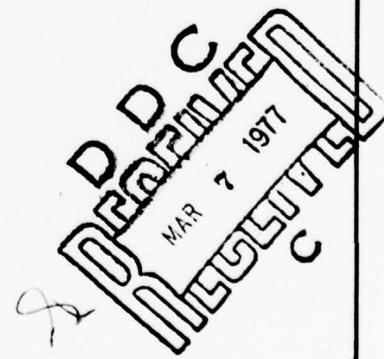
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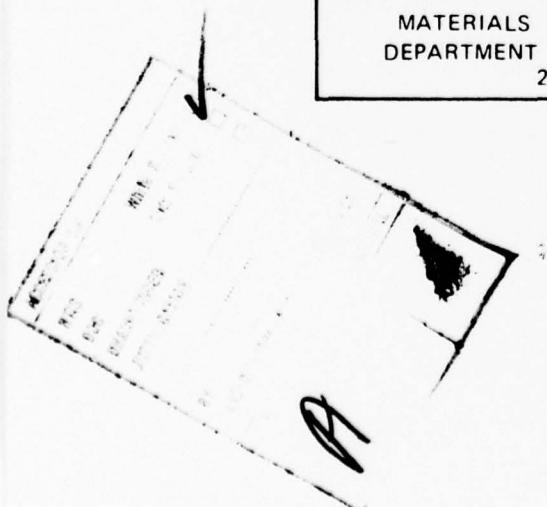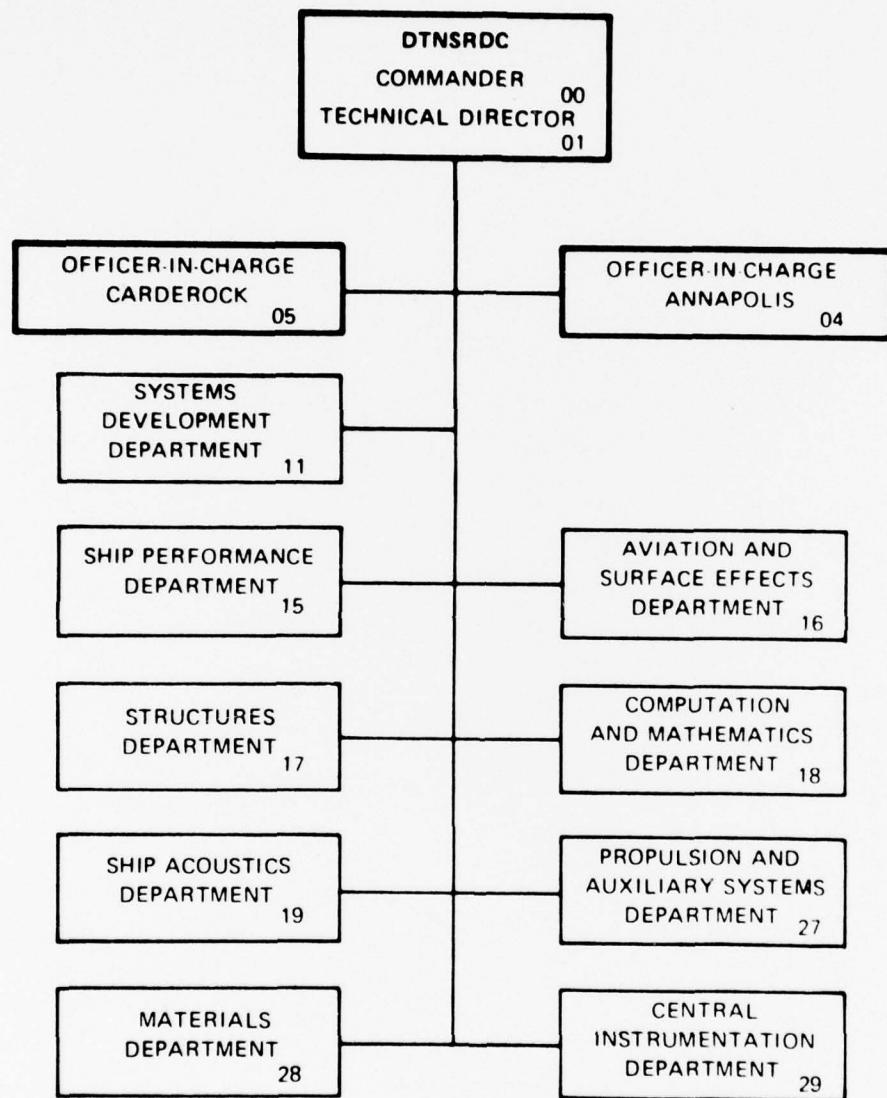
REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER SPD-737-01	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) User's Manual for a FORTRAN IV Computer Program for Calculating the Potential Flow/Boundary Layer Interaction on Axisymmetric Bodies		5. TYPE OF REPORT & PERIOD COVERED Final rept.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) H.T. Wang and T.T. Huang		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS David W. Taylor Naval Ship Research and Development Center Bethesda, Maryland 20084		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Element No. 62543N Task Area SF 43421512 Work Units 1520-004,1500-200
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Sea Systems Command Materials and Mechanics Division Washington, D.C. 20362		12. REPORT DATE December 1976
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

User's Manual
Potential Flow
Boundary Layer
Axisymmetric Bodies

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A description is given of a computer program which calculates the incompressible boundary layer flow and pressure distribution over an axisymmetric body. A brief outline is given of the computation method. Detailed input instructions are provided. A sample problem is solved to illustrate usage of the program and also to present the output. The general output scheme is explained and the output variables are defined.

ABSTRACT

A description is given of a computer program which calculates the incompressible boundary layer flow and pressure distribution over an axisymmetric body. A brief outline is given of the computation method. Detailed input instructions are provided. A sample problem is solved to illustrate usage of the program and also to present the output. The general output scheme is explained and the output variables are defined.

ADMINISTRATIVE INFORMATION

INTRODUCTION

A computer program is documented which calculates the incompressible boundary layer flow and pressure distribution over an axisymmetric body in uniform flow at zero angle of attack.

The computation method, which is more fully described in Reference 1, is first briefly outlined here. Instructions are then provided on the program, including a listing of the input READ statements, the definition of the input variables, a number of comments on usage of the program, and the memory and computer time requirements of the program. A sample problem is presented to illustrate usage of the program. The output for this problem is presented and the output variables are defined.

DESCRIPTION OF COMPUTATION METHOD

The program contains three major calculations. The Douglas Neumann method[2,3] is first used to calculate the potential flow pressure distribution

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[1]Huang, T.T., H.T. Wang, N. Santelli, and N.C. Groves, "Propeller/Hull Interaction on Axisymmetric Bodies: Theory and Experiment," DTNSRDC Report 76-0113 (in review).

[2]Smith, A.M.O. and J. Pierce, "Exact Solution of the Neumann Problem. Calculation of Non-Circulatory Plane and Axially Symmetric Flows About or Within Arbitrary Boundaries," Douglas Aircraft Company Report ES-26988 (Apr 1958).

[3]Hess, J.L. and A.M.O. Smith, "Calculation of Potential Flow About Arbitrary Bodies," from Progress in Aeronautical Sciences, Vol. 8, Pergamon Press, Oxford and New York (1966).

over the original body. In this method, the body is divided into a number of frustrums of cones, each of which has a constant source density on its surface. A set of linear algebraic equations is used to solve for the strengths of these source densities. Once the source densities are known, the pressure coefficients everywhere in the flow field, including the body surface, may be readily determined. This initial pressure distribution, with velocity ratio linearly extrapolated in the stern region, is then used by the Douglas Cebeci-Smith (CS) differential boundary-layer method[4,5,6] to calculate the viscous flow over the body. This method makes the standard thin boundary layer assumption of a constant pressure across the thickness of the layer. The integral wake relations given by Granville[7] are then used to calculate the flow in the wake. These relations are essentially based on experimentally measured wake data behind a body of revolution.

The calculated displacement thicknesses from the boundary layer and wake methods are then used to generate a new overall body-wake displacement model. In the stern/near-wake region, where neither of the two methods properly model the thick boundary layer, a fifth-degree polynomial is used to fair the calculated stern displacement thickness surface into the calculated wake displacement thickness surface. The polynomial coefficients are selected to provide continuous displacements, slopes, and curvatures at the intersections of the polynomial with the calculated stern and wake displacement thickness surfaces. The Douglas Neumann method is again used to calculate the pressure distribution over the resulting body-wake displacement body, which is then used to calculate the new boundary layer flow over

[4] Cebeci, T. and A.M.O. Smith, Analysis of Turbulent Boundary Layers, Academic Press, New York (1974).

[5] Cebeci, T., G.J. Mosinskis, and A.M.O. Smith, "Calculation of Viscous Drag and Turbulent Boundary-Layer Separation on Two-Dimensional and Axisymmetric Bodies in Incompressible Flows," Douglas Aircraft Company Report No. MDC-J0973-01 (Nov 1970).

[6] Cebeci, T., G. Mosinskis, and L.C. Wang, "A Finite-Difference Method for Calculating Compressible Laminar and Turbulent Boundary Layers, Part II - User's Manual," Douglas Aircraft Company Report DAC-67131 (May 1969).

[7] Granville, P.S., "The Calculation of the Viscous Drag of Bodies of Revolution," DTMB Report 849 (Jul 1953).

the body and in the wake. This process is repeated until successive pressure distributions agree to within a specified error criterion at all points along the body-wake displacement surface or until the specified maximum number of iterations is reached. A sketch of the original axisymmetric body, the body-wake displacement surface, and the definition of coordinate systems is given in Figure 1.

In order to simplify the overall program and also to reduce the number of input variables, a number of options in the two Douglas programs which are not directly applicable to the present problem have been deleted. The major deletions include the effect of compressibility contained in both programs, the calculation of vorticity and cross flows in the Douglas-Neumann program, and the option for calculating two-dimensional flows in the Douglas CS program.

On the other hand, the output of the Douglas CS program has been expanded in two areas. First, whereas the original program printed out only the tangential velocity profile, the present program also prints out the normal, axial, and radial velocity profiles in the boundary layer. It should be noted that wake distributions in the propeller disk plane are usually given in terms of the latter two profiles. Secondly, three different methods are used to compute the overall drag acting on the body. Two of these methods, by Squire-Young[5] and Granville,[7] are essentially empirical formulas for the drag based on boundary layer parameters at the stern of the body. They are commonly used in cases where the actual pressure distribution over the body is unknown. The third, and more accurate, method consists of summing the components of drag due to friction and pressure. The resulting drag coefficients are given in terms of three different reference areas: frontal area, wetted area, and $(\text{volume})^{2/3}$.

INPUT INSTRUCTIONS

INPUT STATEMENTS

The input statements by means of which data are entered into the
program are as follows:

```
    READ(5,1012) IPROP, NXMM, IPF, IVF, FLPRNT, TITLP
  *READ(60) (TX1(I), TY1(I), I = 1, NXMM)
 **READ(64) (TX1(I), TY1(I), I = 1, NXMM)
  READ(5.5010) NXT, LG16, LG17
  READ(5,5051) ROMAX, RL, UI, RI
 *READ(5,1013) NTOT, ICUT, ICP
 *READ(5,5025) XA, XTL, XWAK, XSLP, CPERR
 *READ(5,2) (XX(I), I = NN + 1, NTOT)
**READ(22) (UE(I), I = 1, NXMM)
**READ(5,1013) N
**READ(5,2) (X(I), I = 1, N)
**READ(5,2) (Y(I), I = 1, N)
```

*Skip when velocity distribution is input, i.e., IPROP $\geq$ 1.
**Skip when velocity distribution is not input, i.e., IPROP $\leq$ 0.

The corresponding FORMAT statements are as follows:

```
1012 FORMAT (4I3, F8.4, 15A4)
5010 FORMAT (I4, 7I1)
5051 FORMAT (3F10.4, F12.2)
1013 FORMAT (20I4)
5025 FORMAT (8F10.4)
   2 FORMAT (8F10.7)
```

DEFINITION OF INPUT VARIABLES

IPROP	$\geq$1 velocity (pressure) distribution is input
	$\leq$0 velocity distribution is not input
NXMM	Number of body points (typically, NXMM = 140 to 160)
IPF	$\geq$1 output from potential flow program is printed after each iteration

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	≤ 0 output from potential flow program is printed only after initial calculation on original body
IVF	≥ 1 full output from boundary layer program is printed after each iteration
	≤ 0 full output from boundary layer program is printed only after final iteration
FLPRNT	Minimum value of X/RL for which velocity profiles are printed after final iteration
TITLP	Title
TX1(I)	Axial distance measured from nose in feet
TY1(I)	Radius of body at X = TX1(I) in feet
NXT	Index of body station where flow becomes turbulent; if transition is to be calculated by program, NXT > NXMM
LG16	= 0 if transition point is not to be calculated by the program
	= 1 if transition point is to be calculated by the program
LG17	= 0 if transition is instantaneous
	= 1 if transition is gradual
ROMAX	Maximum radius of body/RL
RL	Reference length = body length = TX1(NXMM)
UI	Free-stream velocity in feet/second
RI	Reynolds number/RL
NTOT	Number of body points + number of wake points, must be ≤ 200
ICUT	Maximum number of iterations for pressure on body-wake displacement model, not including initial potential flow calculation on the original body (typically set equal to 3)
ICP	= 0 if pressure coefficient from previous iteration is used to calculate boundary layer flow
	≥ 1 if average of pressure coefficient from previous two iterations are used to calculate boundary layer flow

XA   Value of X/RL where initial guess for wake velocity reaches
            0.99 of free stream velocity UI (typically set equal to
            1.15)

XTL   Value of X/RL where initial potential flow velocity distribution
            is linearly extrapolated to tail (usually set equal to 0.95)

XWAK   Upstream value of X/RL where 5th-degree polynomial matches with
            computed displacement body (usually set XWAK equal to 0.95 or
            two body stations ahead of the separation point, whichever
            occurs first)

XSLP   Downstream value of X/RL at matching point (usually set equal
            to 1.05)

CPERR   Maximum allowable error in pressure coefficient CP along the
            entire body and wake (typically set between 0.005 and 0.02)

XX(I)   Values of X/RL for the wake displacement model (typically
            $1.0 < XX(I) \leq 30$)

UE(I)   Input velocity ratio at the input body points TX1(I), TY1(I)

N   Number of points where changes to input velocity ratio are made

X(I)   Values of X/RL where velocity ratio changes are made, $(X(1)>0,$
            $X(N) = 1.0)$

Y(I)   Velocity ratio change at X/RL = X(I)

COMMENTS ON USAGE

1. In most cases, where full output from the boundary layer program is
desired only for the final pressure distribution, the setting of IVF $\leq$ 0
will give a total output which is typically one-third of the corresponding
output for IVF >1. In the case when IVF$\leq$0 and IPF$<$0, the program still
prints out various overall boundary layer characteristics at the tail of
the body as well as the error in C_p at all points along the surface of the
body-wake displacement model for intermediate iterations.

2. For input values of NXT>NXMM and LG16 = 0, the boundary layer is
assumed to be laminar up to separation, regardless of Reynolds number or
pressure distribution. While such flows are not physically meaningful, they
may be of interest in certain theoretical studies of laminar boundary layers.

3. Since the boundary layer program stops at separation, the program has to be rerun for cases where the separation point occurs ahead of the input value of XWAK, which typically is 0.95. In these cases, the new value of XWAK should be input as a value just less than $TX1(I-2)/RL$, where $TX1(I)RL$ is the value of X/RL where separation occurs.

4. As pointed out above, an input value of $IPROP>1$ means that the velocity distribution is not calculated by the program but is instead input into the program. These distributions may be experimental values or may be the results of a previous calculation using this program. In these cases, the program skips the potential flow calculations and goes directly to the boundary layer calculations.

5. When $IPROP>1$, provision is made in the program for reading in changes to the input velocity distribution. These changes may correspond, for example, to modifications of the input bare hull velocity distribution due to the presence of an operating propeller and/or appendage. For the case where no changes to the input distribution are desired, simply set the quantities $Y(I) = 0$ for $I = 1$ to N.

6. For cases when a device is used to trip turbulent flow, the results of Reference 8 indicate that the tripping device has measurable parasitic drag. The net effect is that the effective location of transition is no longer at the tripping device but is instead moved forward to a virtual origin, which depends on the trip location, geometric information on the body, and computed laminar boundary layer parameters on the forebody. The procedure for making this calculation is given in References 1 and 8 and hence is not repeated here. The value of NXT defined above should be set equal to the index of the body station at the virtual origin.

COMPUTER PROGRAM STORAGE AND TIME REQUIREMENTS

On the CDC 6700 computer currently in use at the Center, the program requires a memory of approximately 145,000 octal words and a period of 70 seconds to compile. Program execution time depends on a number of variables such as the number of body and wake points, and the number of iterations required to arrive at the final results. For a typical example of a body-wake

displacement model described by 170 points, an execution time of approximately 350 seconds is required to make four complete calculations of the pressure distribution, the boundary layer flow, and the wake flow (ICUT = 3). If one uses the overnight computer priority P2, the total cost for this run is approximately $60.

PROGRAM OUTPUT

The output of the program is best illustrated by means of a sample problem.

SAMPLE PROBLEM

The computer program will be used to calculate the pressure and boundary layer on an axisymmetric body designated as Model 4620-3. The body is described by 137 points and is catalogued on permanent file CHHX46203TP60, ID=CHHX. The body has a total length of 10.0 feet and a maximum radius of 0.4475 feet. The body is to be tested in the wind tunnel at an air speed of 217 feet and a corresponding Reynolds number of 1.268×10^7. A transition trip wire is placed on the forebody at $X/RL = 0.05$. With the procedure outlined in Reference 8, the virtual origin of turbulence is calculated to be at $X/RL = 0.015$. Transition may be assumed to be instantaneous. The iterations for pressure are to stop when: (a) the difference in the pressure coefficient C_p between two successive iterations is less than 0.01 at all points along the body-wake displacement surface, or (b) the number of iterations for pressure, after the initial potential flow calculation, is equal to 3. (For most cases, the maximum difference in C_p is less than 0.02 after three iterations.) Use the pressure from the previous iteration to compute the boundary layer and wake flow. Use 171 points to model the body-wake surface. Guess that the wake velocity reaches 0.99 of free stream velocity on the wake surface at $X/RL = 1.15$. In order to avoid separation in the stern region, linearly extrapolate the initial potential-flow velocity distribution to the tail for $X/RL \geq 0.95$. Take the upstream and downstream matching points for the 5th-degree polynomial to be at $X/RL = 0.95$ and 1.05, respectively. Use the short printout options. Velocity profiles are desired for $X/RL \geq 0.90$.

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[8]McCarthy, J.H., J.L. Power, and T.T. Huang, "The Roles of Transition, Laminar Separation, and Turbulence Stimulation in the Analysis of Axisymmetric Body Drag," Eleventh Symposium on Naval Hydrodynamics, London (1976).

SOLUTION

The data cards for this problem are listed in Table 1. The first card attaches the permanent file describing the body points. The other cards follow the order of the READ statements given previously. The symbol b is used to denote a blank. Also, column numbers 1, 11, 21, 31, 41, and 51 have been indicated since most of the data start in these columns.

GENERAL DESCRIPTION OF OUTPUT

Since the short printout options were used for the present problem, the program prints the full output from only the initial pass through the potential flow program and the final pass through the boundary layer and wake programs. Table 2 shows sample portions of each section of the output. The portions which are not shown are simply the remainder of the station data for each section.

The potential flow program first prints the maximum error in the source density for each Seidel iteration of the simultaneous equations for source density. Table 2 shows that a total of eight iterations are required to reach the convergence criterion for the maximum allowable error in source density, which is 1×10^{-6}. The potential flow program then prints various geometric and flow variables, including the pressure coefficient C_p, at each station. After the initial potential flow printout, the boundary layer program prints out the geometry of the body in dimensionless and dimensional coordinates as well as other geometry and input variables.

The following several pages of Table 2 give the abbreviated output for intermediate iterations. The boundary layer program prints out the difference in C_p between successive iterations at each point along the body-wake displacement surface. Table 2 shows that this maximum difference for iterations 1, 2, and 3 is respectively 0.235, 0.025, and 0.013. The program also prints out the drag of the body calculated by three separate methods and referenced to three different areas; several boundary-layer variables at the tail are also printed out. The potential flow program prints out only the maximum error for each Seidel iteration for source density.

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After the final iteration for C_p, the output from the boundary-layer program is greatly expanded. First, the pressure coefficient C_p for the initial potential flow calculation CPPF, the final iterated viscous pressure coefficient CP, and the difference CP-CPPF are printed out at each station. The associated body pressure drag at each station, as well as the cumulative total pressure drag from the nose to the station for the above three cases, are also printed out. Detailed velocity profiles are printed next over the rear of the body. These velocity profiles are given in terms of components normal and tangential to the body as well as in the axial and radial directions. Following these, a summary of local and integrated boundary layer variables at each station is printed. The program concludes by printing the offsets of the final body-wake displacement surface.

DEFINITION OF OUTPUT VARIABLES

The output variables are defined in the order that they appear in Table 2.

Potential Flow Program

X	Dimensional axial distance in feet measured from the nose of the body
Y	Dimensional radius in feet of body
T1	Local tangential velocity/free stream velocity UI
CP	Pressure coefficient = $1 - (T1)^2$
SIN A	Sin α, where α is defined in Figure 1
COS A	Cos α
SIGMA	Source density
N	Local normal velocity/UI
PHI	Perturbation potential due to presence of body

Boundary Layer Program - Part 1

TRFLAG	LG16 (see DEFINITION OF INPUT VARIABLES)
TRINT	LG17 (see DEFINITION OF INPUT VARIABLES)
TVC	= 1, transverse curvature effects are taken into account
SHORTP	= 1, velocity profiles are printed for X/RL $\geq$ FLPRNT

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K	Station number
X/C	Axial distance/RL
S/C	Arc length/RL
Y/C	Radius/RL
X	Axial distance in feet
S	Arc length in feet
Y	Body radius in feet
RL	Body length in feet
RHOREF	ρ = MUREF * RI/UI, density of fluid in slugs/ft^3, based on input Reynolds number/ft RI and velocity UI
MUREF	μ = 0.3834 x 10^{-6} lb sec/ft^2, dynamic viscosity of air at 60°F
UI	Free stream velocity in ft/sec
RI	Reynolds number per foot
RI*RL	= RI*RL, Reynolds number

Boundary Layer Program - Part 2

N	Station number
X/C	Axial distance/RL
S	Arc length in feet
RO/C	Body radius/RL
BETA	β = (2ξ/UE)(dUE/dξ), ξ = SQUIG, dimensionless velocity-gradient term
CP PF	Pressure coefficient calculated using original body, i.e., C_p from initial potential flow calculation
SQUIG	$\xi = \int_o^s UE(\frac{RO}{C})^2$ ds, transformed arc length coordinate in lb^{2}sec^2/ft^4
COS(ALPHA)	Cos α, see Figure 1 for definition of α
SIN(ALPHA)	Sin α
CRINT	= 2 ΔC_p (RO/C)*tanα/(ROMAX)^2, ΔC_p = CP-CPPF
UE	Local tangential velocity calculated by potential flow program using latest body-wake displacement model in ft/sec
CP	= 1 - (UE/UI)^2, pressure coefficient calculated using the latest body-wake displacement model
MUE	= 0.3834 x 10^{-6} lb sec/ft^2, dynamic viscosity of air at 60°F

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CRLPF $= 2\ CP\ PF * DR/(ROMAX)^2$, $CP\ PF = (CP\ PF(N) + CP\ PF(N-1))/2$,
             $DR = RO(N)/C - RO(N-1)/C$, component of CP PF in axial
             direction referenced to frontal area

CRLVF $= 2\ CP * DR/(ROMAX)^2$, $CP = (CP(N) + CP(N-1))/2$, component
             of CP in axial direction referenced to frontal area

CRLDF   = CRLVF - CRLPF

CRAPF $= \sum\limits_{I=1}^{N}\ CRLPF(I)$, cumulative total from nose to station N of CRLPF

CRAVF $= \sum\limits_{I=1}^{N}\ CRLVF(I)$, cumulative total from nose to station N of CRLVF

CRADF $= \sum\limits_{I=1}^{N}\ CRLDF(I)$, cumulative total from nose to station N of CRLDF

CRAFA,   Drag component of (CP - CP PF) for the entire body referenced
CRAWA,   to (frontal area, wetted area, $(volume)^{2/3}$), note: CRAFA =
CRAV23   CRADF(NXMM)

Boundary Layer Program - Part 3

I   Station number

ETA $\eta = \int_{o}^{y} \frac{\rho UE}{\sqrt{2\xi}}\ (\frac{RO}{c})dy$, transfomed y-coordinate, y = distance measured

             normal to body (see Figure 1)

F $= \dfrac{\psi}{\sqrt{2\xi}\ (RL)}$, ψ = stream function, F = dimensionless stream function

FP $= \partial f/\partial \eta = u/UE$, u = tangential velocity in ft/sec

FPP $= \partial^2 f/\partial \eta^2 = \partial(u/UE)/\partial \eta$

Y   y, distance measured normal to body in feet (see Figure 1)

EPS+ $\epsilon+ = \epsilon/\nu$, ϵ = eddy viscosity, $\nu = \mu/\rho$ = kinematic viscosity

UPLUS $u+ = (u/UE)/\sqrt{c_f/2}$, c_f = local skin-friction coefficient

VVEL/UE   = v/UE, v = velocity normal to body in ft/sec

X/C   Axial distance measured from nose/RL

R/C   Radial distance measured from body axis/RL

R/RMAX   Radial distance measured from body axis/maximum radius of body

R-RO/RM   Radial distance measured from body surface/RMAX, RO = radius of
             body in feet

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UX	$= u_x/UE$, u_x = axial component of velocity in ft/sec
UR	$= u_R/UE$, u_R = radial component of velocity in ft/sec
UTOT	$= \sqrt{UX^2 + UR^2}$

Boundary Layer Program - Part 4

N	Station number
S	Arc length measured from nose in feet
THETA	$\theta = \int_0^\infty \frac{R}{R0} \frac{u}{UE} \left(1 - \frac{u}{UE}\right) dy$, momentum thickness in feet
DELS	$\delta^* = \int_0^\infty \frac{R}{R0} \left(1 - \frac{u}{UE}\right) dy$, displacement thickness in feet
CF	$C_f = \tau_w/(1/2\rho UE^2)$, τ_w = shear stress at the wall, local skin friction coefficient referenced to local velocity UE
CRL	= CRLDF, see Boundary Layer Program - Part 2 (BLPP2)
CD(CALC)	= CRA(N) + CFA, CRA(N) = CRADF defined in BLPP2, cumulative total from nose to station N of drag coefficient due to pressure and friction, referenced to frontal area
CD(GRAN)	$= \frac{4\pi(R0)\theta}{\pi(RMAX)^2} \left(\frac{UE}{UI}\right)^{[7(H+2) + 3]/8}$, RMAX = maximum radius of body, drag coefficient referenced to frontal area computed by the Granville[7] formula from nose to station N
IMAX	Total number of points in the η-direction required to reach the outer edge of the boundary layer where u/UE = 1
X/C	Axial coordinate/RL
RX	$= (UE)S/\nu$, ν = kinematic viscosity, Reynolds number based on arc length S and local velocity UE
RTHETA	$= (UE)\theta/\nu$, Reynolds number based on momentum thickness θ and local velocity UE
H	$= \delta^*/\theta$, shape factor
DEL(GRAN)	$= \frac{-R0 + \sqrt{R0^2 + 2R0\delta^*\cos \alpha}}{\cos \alpha}$, effective thickness due to displacement effect of boundary layer to be added to original body to obtain body-wake displacement surface, in feet
CFA	Cumulative skin friction coefficient from nose to station N, referenced to free stream velocity UI and frontal area

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CRA = CRADF defined in BLPP2

CD(SQ-YN) = $\frac{4\pi(RO)\theta}{\pi(RMAX)^2}$ $(\frac{UE}{UI})^{(H+5)/2}$, drag coefficient referenced to frontal area computed by the Squire-Young formula[5]

ETAINF Value of η at outer edge of boundary layer where $u/UE = 1$

CDT(CALC) = CRAFA + CRA, CRAFA is defined in BLPP2, sum of (total drag coefficient on entire body due to pressure) and (cumulative skin friction coefficient from nose to station N) referenced to UI and frontal area

WA,V23,FA Subscripts indicating that the drag coefficient is referenced to (wetted area, $(volume)^{2/3}$, frontal area)

N Station number

(X/C)OLD Axial distance of a point on the original body/RL

RO Radius of body in feet

DELS δ^*, displacement thickness in feet

DELGR = DEL(GRAN), effective thickness in feet to be added to original body to obtain body-wake displacement surface

(RO + DELG)/C = (RO + DELGR)/RL, (body radius + effective thickness)/RL, dimensionless radius of body-wake displacement surface, assuming the effective thickness is added normal to the x-axis

(X/C)NEW, (RO + DG*COS)/C Value of (X/RL, R/RL) at surface of body-wake displacement model, assuming the effective thickness is added normal to the surface of the original body

U TAIL, X TAIL, H TAIL Value of (UE/UI, X/RL, H) at tail of original body

GAMA TAIL = $(\frac{RO}{RL})^2 \frac{CDC\ FA}{(U\ TAIL)} [7(H\ TAIL + 2) + 3]/8$, initial value of dimensionless momentum area for the start of the wake calculations, based on overall drag coefficient CDC FA and velocity ratio at the tail (derivation is given in Reference 1)

Wake Program

X^* Axial distance measured from nose in feet

MOM AREA* = $\int_0^\infty R \frac{u}{UE} (1-\frac{u}{UE})\ dy = (RO)(\theta)$, momentum area in ft^2

FORM FAC H* = DISP AREA/MOM AREA, form factor

DISP AREA* = $\int_0^\infty R(1-\frac{u}{UE})\ dy = (RO)(\delta^*)$, displacement area in ft^2

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EFF THICK*   = $\sqrt{2(\text{DISP AREA})}$, effective radius of wake in feet

U/UINF   = UE/UI in wake

CP   = $1 - (\text{U/UINF})^2$

*The dimensional definitions are given. The dimensionless quantities are divided by the appropriate power of body length RL.

COMPARISON OF RESULTS FOR TWO DIFFERENT TRANSITION LOCATIONS

In order to assess the importance of using the virtual origin as the location of transition, a second computer run was made in which all of the input parameters were kept the same except that transition was assumed to be at the trip wire location, $X/RL = 0.05$. Table 3 shows the results at the tail of the body for the two assumed locations of transition. The differences are, on the whole, not large. The largest differences, approximately 1 to 2 percent, occur for the drag coefficients CFA WA, CRA WA, CDC WA, and the boundary layer displacement thickness DELS. These are due to the parasitic drag and boundary layer thickening effect of the trip wire. On the other hand, the shape factor H TAIL and the velocity ratio U TAIL agree to nearly four significant figures.

ACKNOWLEDGEMENT

The authors wish to thank Dr. Tuncer Cebeci of McDonnell Douglas Corporation with whom the authors had a number of helpful technical discussions.

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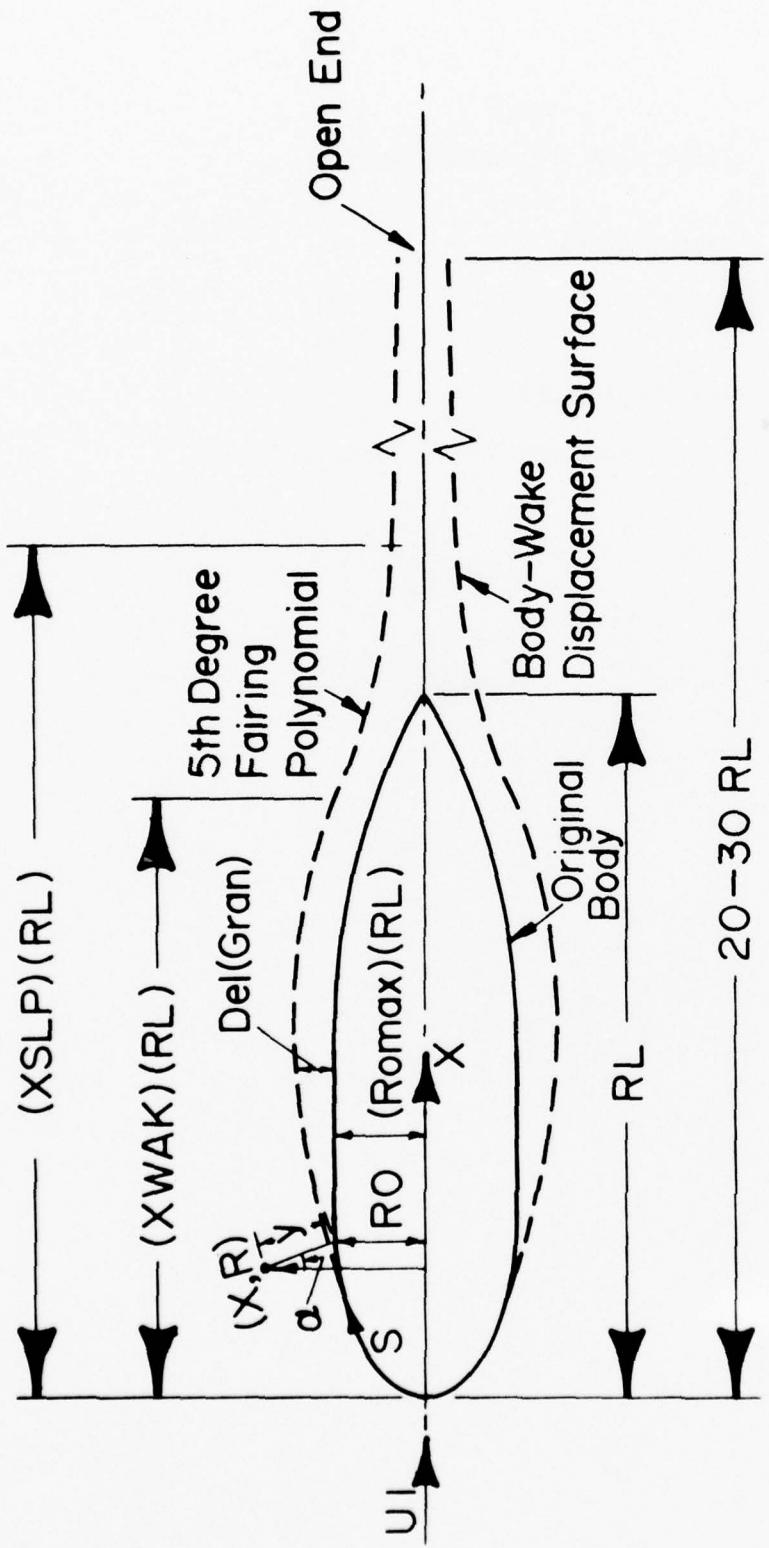
Figure I—Definition Sketch of Original Body and Body—Wake Displacement Surface

TABLE 1

INPUT DATA FOR SAMPLE PROBLEM

Column Number

1	11	21	31	41	51

ATTACH,TAPE60,CHHX46203TP60,ID=CHHX.

bb0137bb0bb0b0.90   CALCULATIONS FOR MODEL 4620-3

bbb400

0.04475   10.00   217.   1268000.

b171bbb3bbb0

1.15   0.95   0.95   1.05   0.01

TABLE 2

PROGRAM OUTPUT

DOUGLAS AIRCRAFT COMPANY
LONG BEACH DIVISION

POTENTIAL FLOW CALCULATIONS

CP ITERATION 0
1   .35834E-01
2   .14388E-01
3   .37J88E-02
4   .79007E-03
5   .13149E-03   .842E+00   .274E+00   .692E+00

6   .13889E-04
7   .12288E-05
8   .90450E-06

8 ITERATIONS REQUIRED FOR CONVERGENCE

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DOUGLAS AIRCRAFT COMPANY
LONG BEACH DIVISION

POTENTIAL FLOW CALCULATIONS   CASE NO.

ON-BODY UNIFORM AXISYMMETRIC FLOW
TRANSFORMED COORDINATES

	X	Y	T1	CP	SIN A	COS A	SIGMA	N	PHI
1	0.00000000	0.00000000	.44145142	.80512065	.89657	.44290	-.08221006	-.00000286	-.16313043
2	.02500000	.05060867	.81516110	.33551238	.64239	.76637	-.05303833	-.00000201	-.15505663
3	.05000000	.10121734	.88463477	.21742132	.54051	.84134	-.04562050	-.00000160	-.15157294
4	.07500000	.14312855	.92726430	.14018091	.47531	.87982	-.04051249	-.00000134	-.14849546
5	.10000000	.15518943	.95485142	.08825876	.43220	.90178	-.03636340	-.00000120	-.14566519
6	.12500000	.17525031	.97158273	.05602700	.40168	.91578	-.03459066	-.00000108	-.14312473
7	.15000000	.18875623	.98573644	.02820538	.37590	.92666	-.03255425	-.00000098	-.14050465
8	.17500000	.20226215	.99788592	.00422368	.35609	.93445	-.03046615	-.00000093	-.13810198
9	.20000000	.21184774	1.00699983	-.01404860	.33138	.94350	-.02912534	-.00000079	-.13568734
10	.22500000	.22143332	1.02392888	-.04843035	.29887	.95429	-.02646661	-.00000071	-.12913257
11	.25000000	.23225575	1.03918760	-.07991087	.27370	.96182	-.02423406	-.00000069	-.12391095
12	.27500000	.23897817	1.04698327	-.09617397	.25573	.96675	-.02272653	-.00000065	-.11972024
13	.30000000	.24709117	1.05467138	-.11190989	.23855	.97113	-.02123729	-.00000062	-.11539225
14	.32500000	.25520416	1.06126459	-.12628253	.22195	.97506	-.01976466	-.00000060	-.11093008
15	.35000000	.26392011	1.06733500	-.13924400	.20578	.97860	-.01830016	-.00000058	-.10634723
16	.37500000	.26663605	1.07265107	-.15062282	.18996	.98180	-.01683704	-.00000056	-.10166097
17	.40000000	.27892879	1.07793795	-.16047804	.17436	.98468	-.01577189	-.00000054	-.09649128
18	.42500000	.29122153	1.08106315	-.16869752	.15903	.98727	-.01393393	-.00000053	-.09206059
19	.45000000	.30374912	1.08406713	-.17520155	.14392	.98953	-.01243502	-.00000051	-.08719135
20	.47500000	.31627671	1.08621652	-.17990978	.12905	.99164	-.01036930	-.00000050	-.08231655
21	.50000000	.32239082	1.08759141	-.18274631	.11446	.99343	-.00951306	-.00000049	-.07745915
22	.52500000	.33050493	1.08795464	-.18364531	.10020	.99497	-.00887479	-.00000049	-.07265118

****** CEBECI-KELLER BOUNDARY LAYER PROGRAM ******

CALCULATIONS FOR MODEL 4620-3

PROGRAM K90A

CASE .

CASE DATA

TRFLAG = 0   TRINT = 0   TRVC = 1   TVC = 1   SHORTP = 1

TRANSITION SPECIFIED AT STATION 4

BODY GEOMETRY DATA

K	X/C	S/C	Y/C	X	S	Y
1	0.	0.	0.	0.	0.	0.
2	.5000000E-02	.1129935E-01	.1012173E-01	.5000000E-01	.1128935E+00	.1012173E+00
3	.1000000E-01	.1781354E-01	.1431286E-01	.1000000E+00	.1781354E+00	.1431286E+00
4	.1500000E-01	.2375648E-01	.1752503E-01	.1500000E+00	.2375648E+00	.1752503E+00
5	.2000000E-01	.2943947E-01	.2022622E-01	.2000000E+00	.2943947E+00	.2022622E+00
6	.2400000E-01	.3387516E-01	.2214333E-01	.2400000E+00	.3387516E+00	.2214333E+00
7	.2800000E-01	.3824302E-01	.2389782E-01	.2800000E+00	.3824302E+00	.2389782E+00
8	.3200000E-01	.4259560E-01	.2552042E-01	.3200000E+00	.4259561E+00	.2552042E+00
9	.3500000E-01	.4577033E-01	.2666361E-01	.3500000E+00	.4577003E+00	.2666361E+00
10	.4200000E-01	.5318923E-01	.2912215E-01	.4200000E+00	.5318923E+00	.2912215E+00
11	.5000000E-01	.6157240E-01	.3162767E-01	.5000000E+00	.6157240E+00	.3162767E+00
12	.5500000E-01	.6677090E-01	.3305049E-01	.5500000E+00	.6677093E+00	.3305049E+00
13	.6000000E-01	.7194288E-01	.3437311E-01	.6000000E+00	.7194289E+00	.3437311E+00
14	.6500000E-01	.7709151E-01	.3560131E-01	.6500000E+00	.7709151E+00	.3560131E+00
15	.7000000E-01	.8221941E-01	.3673942E-01	.7000000E+00	.8221941E+00	.3673942E+00
16	.7500000E-01	.8732875E-01	.3779080E-01	.7500000E+00	.8732875E+00	.3779080E+00
17	.8000000E-01	.9242146E-01	.3875038E-01	.8000000E+00	.9242146E+00	.3875038E+00
18	.8500000E-01	.9749924E-01	.3964347E-01	.8500000E+00	.9749924E+00	.3964347E+00
19	.9000000E-01	.1025637E+00	.4044886E-01	.9000000E+00	.1025637E+01	.4044886E+00
20	.9500000E-01	.1076163E+00	.4117602E-01	.9500000E+00	.1076163E+01	.4117602E+00
21	.1000000E+00	.1126585E+00	.4182671E-01	.1000000E+01	.1126585E+01	.4182671E+00
22	.1050000E+00	.1176915E+00	.4240278E-01	.1050000E+01	.1176915E+01	.4240278E+00
23	.1100000E+00	.1227168E+00	.4290531E-01	.1100000E+01	.1227168E+01	.4290531E+00
24	.1150000E+00	.1277356E+00	.4333966E-01	.1150000E+01	.1277356E+01	.4333966E+00
25	.1200000E+00	.1327489E+00	.4370557E-01	.1200000E+01	.1327493E+01	.4370557E+00
26	.1250000E+00	.1375809E+00	.4400730E-01	.1250000E+01	.1375809E+01	.4400730E+00
27	.1300000E+00	.1427673E+00	.4424869E-01	.1300000E+01	.1427673E+01	.4424869E+00
28	.1350000E+00	.1476703E+00	.4443429E-01	.1350000E+01	.1476703E+01	.4443429E+00
29	.1400000E+00	.1527631E+00	.4466050E-01	.1400000E+01	.1527631E+01	.4466050E+00
30	.1450000E+00	.1577000E+00	.4471475E-01	.1450000E+01	.1577702E+01	.4471475E+00
31	.1500000E+00	.1627702E+00	.4474078E-01	.1500000E+01	.1627702E+01	.4474078E+00
32	.1550000E+00	.1677703E+00	.4474843E-01	.1550000E+01	.1677703E+01	.4474843E+00
33	.1600000E+00	.1727703E+00	.4474843E-01	.1600000E+01	.1727703E+01	.4474843E+00
34	.1650000E+00	.1777703E+00	.4474843E-01	.1650000E+01	.1777703E+01	.4474843E+00
35	.1700000E+00	.1822703E+00	.4474843E-01	.1700000E+01	.1822703E+01	.4474843E+00

CASE   ****** CEBECI-KELLER BOUNDARY LAYER PROGRAM ******   PROGRAM K9QA
                                        BODY GEOMETRY DATA

K	X/C	S/C	Y/C	X	S	Y
132	.9910000E+00	.1007106E+01	.2481453E-02	.9910000E+01	.1007105E+02	.2481453E-01
133	.9930000E+00	.1009179E+01	.1936865E-02	.9930000E+01	.1009179E+02	.1936865E-01
134	.9940000E+00	.1010216E+01	.1662269E-02	.9940000E+01	.1010216E+02	.1662269E-01
135	.9960000E+00	.1012291E+01	.1107589E-02	.9960000E+01	.1012291E+02	.1107589E-01
136	.9980000E+00	.1014370E+01	.5419400E-03	.9980000E+01	.1014370E+02	.5419400E-02
137	.1000000E+01	.1016407E+01	.1550150E-03	.1000000E+02	.1016407E+02	.1550150E-02

WET AREA	FRONT AREA	VOLUME	WET A/FT A	VOL**2/3	VOL**2/3/FT A	VOL/FT A
.236580E+06	.629124E-02	.486438E-02	.379226E+02	.287090E-01	.456334E+01	.773200E+00

RL	RHOREF	MUREF	UI	RI	RI*RL
.100000E+02	.224041E-02	.383414E-06	.21700CE+03	.126800E+07	.126800E+08

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****** CEBECI-KELLER BOUNDARY LAYER PROGRAM ******

OUTPUT SUMMARY

PROGRAM K90A

CASE

N X/C CDT(CALC)	S RX CRL MA	THETA RTHETA CRA MA	DELS H CFA MA	CF DEL(GRAN) COCAL MA	CRL CFA COTCAL MA	CO(CALC) CRA CDGR MA	CO(GRAN) CO(SQ-VN) COSY MA	IIAX ETAINF
COC V2/3 .024623	CDGR V2/3 .024987	COSY V2/3 .025331	COC MA .002963	CDGR MA .003007	COSY MA .003048	COC FA .112361	CDGR FA .114025	COSY FA .115593
U TAIL .8972206	X TAIL 1.0000000	GAMA TAIL .0000805	M TAIL 1.3430086	REF LEN 10.0000000				

********** CASE TERMINATED **********

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DOUGLAS   AIRCRAFT   COMPANY
LONG   BEACH   DIVISION

POTENTIAL FLOW CALCULATIONS

     CP ITERATION 1
1   .35964E-01
2   .14487E-01
3   .37613E-02
4   .81065E-03
5   .13815E-03
                              .841E+00   .278E+00   .687E+00
6   .15746E-04
7   .10874E-05
8   .80259E-06

     8   ITERATIONS REQUIRED FOR CONVERGENCE

     N   X MIDPOINT   CP ERROR
     1   .002500   .002328
     2   .007500   .002431
     3   .012500   .002863
     4   .017500   .003427
     5   .022000   .002587
     6   .026000   .002155
     7   .030000   .002033
     8   .033500   .001998
     9   .038500   .001844
    10   .046000   .001740
    11   .052500   .001840
    12   .057500   .001876
    13   .062500   .001862
    14   .067500   .001887
    15   .072500   .001946
    16   .077500   .002008
    17   .082500   .002094
    18   .087500   .002173
    19   .092500   .002218
    20   .097500   .002278
    21   .102500   .002353
    22   .107500   .002398
    23   .112500   .002427
    24   .117500   .002426
    25   .122500   .002386
    26   .127500   .002294
    27   .132500   .002139
    28   .137500   .001901
    29   .142500   .001563
    30   .147500   .001107
    31   .152500   .000526
    32   .157500   .000109
    33   .162500   .000623
    34   .167500   .000864
    35   .172500   .000873
    36   .177500   .000791
    37   .182500   .000703
    38   .187500   .000632
    39   .192500   .000581

25

40	.197500	.000526
41	.205000	.000433
42	.215000	.000379
43	.225000	.000346
44	.235000	.000318
45	.245000	.000285
46	.255000	.000261
47	.265000	.000256
48	.275000	.000241
49	.285000	.000229
50	.295000	.000230
51	.305000	.000226
52	.315000	.000223
53	.325000	.000221
54	.335000	.000220
55	.345000	.000219
56	.355000	.000219
57	.365000	.000220
58	.375000	.000221
59	.385000	.000224
60	.395000	.000227
61	.405000	.000231
62	.415000	.000236
63	.425000	.000243
64	.435000	.000251
65	.445000	.000261
66	.455000	.000272
67	.465000	.000284
68	.475000	.000298
69	.485000	.000314
70	.495000	.000333
71	.505000	.000355
72	.515000	.000380
73	.525000	.000409
74	.535000	.000444
75	.545000	.000485
76	.555000	.000533
77	.565000	.000588
78	.575000	.000637
79	.585000	.000586
80	.595000	.000189
81	.605000	.000642
82	.616275	.001498
83	.626362	.002077
84	.635893	.001874
85	.645425	.001793
86	.654956	.001542
87	.666394	.001434
88	.675926	.001470
89	.685458	.001308
90	.696895	.001268
91	.706427	.001358
92	.715959	.001327
93	.725491	.001439
94	.735022	.001348
95	.746460	.001453
96	.755992	.001695
97	.765523	.001647
98	.776961	.001804
99	.786493	.002143
100	.796024	.002226
101	.805556	.002596
102	.815087	.002588
103	.826525	.002934
104	.836057	.003624
105	.845588	.003559

106	.857026	.003983
107	.866558	.004971
108	.876089	.004954
109	.885621	.006134
110	.895153	.005660
111	.906590	.005919
112	.916122	.007752
113	.924968	.006138
114	.935080	.003530
115	.945000	.003078
116	.953500	.009580
117	.959500	.015588
118	.964500	.024754
119	.968500	.032013
120	.971000	.038333
121	.973000	.045317
122	.974500	.049492
123	.975500	.053306
124	.977000	.060950
125	.978500	.066058
126	.980800	.074651
127	.982000	.084969
128	.984000	.096377
129	.986000	.108979
130	.988000	.122994
131	.990000	.138780
132	.992000	.157001
133	.993500	.172063
134	.995000	.191808
135	.997000	.232047
136	.999300	.234576

MAX CP ERROR=   .234576

CASE

****** CEBECI-KELLER BOUNDARY LAYER PROGRAM ******
OUTPUT SUMMARY

N	S	THETA	DELS	CF	CRL	CD(CALC)	CD(GRAN)	IMAX
X/C	RX	RTHETA	H	DEL(GRAN)	CFA	CRA	CD(SQ-VN)	E1A1NF
CD(CALC)	CRL MA	CRA MA	CFA MA	CDCAL MA	CDTCAL MA	CDGR MA	CDSY MA	

CDC V2/3	COGR V2/3	COSY V2/3	CDC MA	CDGR MA	COSY MA	CDC FA	CDGR FA	CDSY FA
.024883	.024718	.024836	.002934	.002974	.002989	.113551	.112799	.113336

U TAIL	X TAIL	GAMA TAIL	H TAIL	REF LEN
.9557514	1.000000	.0000658	1.2687467	10.0000000

********** CASE TERMINATED **********

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POTENTIAL FLOW CALCULATIONS

CP ITERATION 2
1	.35964E-01
2	.14487E-01
3	.37611E-02
4	.81050E-03
5	.13808E-03

.841E+00   .277E+00   .686E+00

6	.15720E-04
7	.10914E-05
8	.80650E-06

8 ITERATIONS REQUIRED FOR CONVERGENCE

N	X MIDPOINT	CP ERROR
1	.002500	.000000
2	.007500	.000001
3	.012500	.000012
4	.017500	.000037
5	.022000	.000033
6	.026000	.000004
7	.030000	.000004
8	.033500	.000001
9	.038500	.000001
10	.046000	.000001
11	.052500	.000001
12	.057500	.000002
13	.062500	.000001
14	.067500	.000001
15	.072500	.000002
16	.077500	.000004
17	.082500	.000006
18	.087500	.000008
19	.092500	.000010
20	.097500	.000012
21	.102500	.000016
22	.107500	.000021
23	.112500	.000026
24	.117500	.000032
25	.122500	.000038
26	.127500	.000044
27	.132500	.000050
28	.137500	.000052
29	.142500	.000048
30	.147500	.000031
31	.152500	.000005
32	.157500	.000053
33	.162500	.000090
34	.167500	.000097
35	.172500	.000077
36	.177500	.000049
37	.182500	.000029
38	.187500	.000017
39	.192500	.000012

40	.197500	.000007
41	.205000	.000002
42	.215000	.000001
43	.225000	.000001
44	.235000	.000001
45	.245000	.000002
46	.255000	.000003
47	.265000	.000003
48	.275000	.000003
49	.285000	.000004
50	.295000	.000003
51	.305000	.000001
52	.315000	.000001
53	.325000	.000002
54	.335000	.000003
55	.345000	.000004
56	.355000	.000004
57	.365000	.000004
58	.375000	.000004
59	.385000	.000005
60	.395000	.000005
61	.405000	.000005
62	.415000	.000005
63	.425000	.000005
64	.435000	.000006
65	.445000	.000006
66	.455000	.000006
67	.465000	.000006
68	.475000	.000006
69	.485000	.000005
70	.495000	.000005
71	.505000	.000004
72	.515000	.000002
73	.525000	.000000
74	.535000	.000005
75	.545000	.000013
76	.555000	.000027
77	.565000	.000052
78	.575000	.000089
79	.585000	.000107
80	.595000	.000062
81	.605000	.000047
82	.616275	.000158
83	.626362	.000225
84	.635893	.000163
85	.645425	.000104
86	.654956	.000062
87	.666394	.000046
88	.675926	.000046
89	.685458	.000036
90	.696895	.000035
91	.706427	.000047
92	.715959	.000056
93	.725491	.000055
94	.735022	.000051
95	.746460	.000070
96	.755992	.000093
97	.765523	.000088
98	.776961	.000107
99	.786493	.000146
100	.796024	.000184
101	.805556	.000204
102	.815087	.000214
103	.826525	.000303
104	.836057	.000401
105	.845588	.000433

106	.857026	.000603
107	.866558	.000844
108	.876089	.001186
109	.885621	.001544
110	.895153	.001950
111	.906590	.003327
112	.916122	.005521
113	.924968	.007021
114	.935000	.007794
115	.945000	.007225
116	.953500	.007082
117	.959500	.007403
118	.964500	.006806
119	.968500	.006225
120	.971000	.005444
121	.973000	.004463
122	.974500	.003895
123	.975500	.003321
124	.977000	.002223
125	.978500	.001484
126	.980000	.000288
127	.982000	.001114
128	.984000	.002607
129	.986000	.004167
130	.988000	.005782
131	.990000	.007437
132	.992000	.009110
133	.993500	.010468
134	.995000	.011666
135	.997000	.013355
136	.999000	.015022
137	1.001000	.016652
138	1.003000	.018234
139	1.005000	.019756
140	1.007000	.021220
141	1.009000	.022711
142	1.012000	.023863
143	1.017000	.025390
144	1.025000	.024137
145	1.035000	.020147
146	1.045000	.011268
147	1.057000	.001933
148	1.072000	.002446
149	1.090000	.002694
150	1.110000	.002480
151	1.135000	.001767
152	1.175000	.000960
153	1.225000	.000610
154	1.275000	.000378
155	1.325000	.000249
156	1.375000	.000197
157	1.450000	.000121
158	1.550000	.000105
159	1.675000	.000077
160	1.875000	.000047
161	2.200000	.000024
162	2.700000	.000010
163	3.300000	.000004
164	4.050000	.000001
165	5.250000	.000000
166	6.750000	.000000
167	8.750000	.000000
168	12.000000	.000000
169	17.000000	.000000
170	25.000000	.000000

MAX CP ERROR=   .025390

CASE

CEBECI-KELLER BOUNDARY LAYER PROGRAM
OUTPUT SUMMARY

PROGRAM K90A

N X/C CD(CALC)	S RX CRL MA	THETA RTHETA CRA MA	DELS H CFA MA	CF DEL(GRAN) COCAL MA	CRL CFA COTCAL MA	CD(CALC) CRA CDGR MA	CD(GRAN) CD(SQ-VM) COSY MA	IMAX ETAINF
CDC V2/3 .025252	CDGR V2/3 .024780	COSY V2/3 .024923	CDC MA .003039	CDGR MA .002982	COSY MA .002999	CDC FA .115234	CDGR FA .113080	COSY FA .113732
U TAIL .9474304	X TAIL 1.0000000	GAMA TAIL .0000647	H TAIL 1.2784373	REF LEN 10.0000000				

########## CASE TERMINATED ##########

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POTENTIAL FLOW CALCULATIONS

```
    CP ITERATION  3
1       .35964E-01
2       .14487E-01
3       .37611E-02
4       .81053E-03
5       .13809E-03
                          .841E+00    .278E+00    .689E+00
6       .15726E-04
7       .10906E-05
8       .80568E-06

    8  ITERATIONS REQUIRED FOR CONVERGENCE
```

N	X MIDPOINT	CP ERROR
1	.002500	.000000
2	.007500	.000001
3	.012500	.000001
4	.017500	.000001
5	.022000	.000001
6	.026000	.000001
7	.030000	.000001
8	.033500	.000001
9	.038500	.000001
10	.046000	.000001
11	.052500	.000001
12	.057500	.000001
13	.062500	.000001
14	.067500	.000001
15	.072500	.000001
16	.077500	.000001
17	.082500	.000001
18	.087500	.000001
19	.092500	.000001
20	.097500	.000001
21	.102500	.000002
22	.107500	.000002
23	.112500	.000002
24	.117500	.000002
25	.122500	.000003
26	.127500	.000003
27	.132500	.000004
28	.137500	.000005
29	.142500	.000006
30	.147500	.000005
31	.152500	.000002
32	.157500	.000003
33	.162500	.000007
34	.167500	.000007
35	.172500	.000004
36	.177500	.000000
37	.182500	.000003
38	.187500	.000003
39	.192500	.000003

40	.197500	.000003
41	.205000	.000003
42	.215000	.000002
43	.225000	.000002
44	.235000	.000002
45	.245000	.000002
46	.255000	.000002
47	.265000	.000002
48	.275000	.000002
49	.285000	.000002
50	.295000	.000002
51	.305000	.000002
52	.315000	.000002
53	.325000	.000002
54	.335000	.000002
55	.345000	.000003
56	.355000	.000003
57	.365000	.000003
58	.375000	.000003
59	.385000	.000003
60	.395000	.000003
61	.405000	.000003
62	.415000	.000003
63	.425000	.000003
64	.435000	.000003
65	.445000	.000003
66	.455000	.000004
67	.465000	.000004
68	.475000	.000004
69	.485000	.000004
70	.495000	.000005
71	.505000	.000005
72	.515000	.000005
73	.525000	.000006
74	.535000	.000006
75	.545000	.000006
76	.555000	.000004
77	.565000	.000001
78	.575000	.000010
79	.585000	.000014
80	.595000	.000008
81	.605000	.000010
82	.616275	.000027
83	.626362	.000037
84	.635893	.000023
85	.645425	.000009
86	.654956	.000003
87	.666394	.000003
88	.675926	.000004
89	.685458	.000004
90	.696895	.000005
91	.706427	.000007
92	.715959	.000008
93	.725491	.000007
94	.735022	.000005
95	.746460	.000006
96	.755992	.000007
97	.765523	.000002
98	.776961	.000000
99	.786493	.000002
100	.796024	.000000
101	.805556	.000011
102	.815087	.000023
103	.826525	.000033
104	.836057	.000051
105	.845588	.000088

106	.857026	.000129
107	.866558	.000164
108	.876089	.000209
109	.885621	.000387
110	.895153	.000399
111	.906590	.000078
112	.916122	.001001
113	.924968	.001945
114	.935000	.002518
115	.945000	.003191
116	.953500	.004798
117	.959500	.006516
118	.964500	.007091
119	.968500	.007403
120	.971000	.007248
121	.973000	.006808
122	.974500	.006630
123	.975500	.006344
124	.977000	.005674
125	.978500	.005355
126	.980000	.004590
127	.982000	.003760
128	.984000	.002846
129	.986000	.001866
130	.988000	.000832
131	.990000	.000244
132	.992000	.001351
133	.993500	.002195
134	.995000	.003057
135	.997000	.004196
136	.999000	.005331
137	1.001000	.006449
138	1.003000	.007541
139	1.005000	.008598
140	1.007000	.009619
141	1.009000	.010649
142	1.012000	.011568
143	1.017000	.012774
144	1.025000	.012267
145	1.035000	.009750
146	1.045000	.003642
147	1.057000	.002651
148	1.072000	.004267
149	1.090000	.002229
150	1.110000	.000924
151	1.135000	.000321
152	1.175000	.000042
153	1.225000	.000015
154	1.275000	.000016
155	1.325000	.000018
156	1.375000	.000012
157	1.450000	.000007
158	1.550000	.000004
159	1.675000	.000001
160	1.875000	.000001
161	2.200000	.000000
162	2.700000	.000000
163	3.300000	.000000
164	4.050000	.000000
165	5.250000	.000000
166	6.750000	.000000
167	8.750000	.000000
168	12.000000	.000000
169	17.000000	.000000
170	25.000000	.000000

MAX CP ERROR=   .012774

N	X/C COS(ALPHA) CRLPF	S SIN(ALPHA) CRLVF	R0/C CRINT CRLDF	BETA UE CRAPF	CP PF CP CRAVF	SQUIG MUE CRADF
1	0. .49936E-05	0. .340283E+00 .49936E-05	.10000E-03 0. 0.	.50000E+00 .499360E-05	.100000E+01 .100000E-01 .499360E-05	0. .383414E-06 0.
2	.50000E-02 .64790E+00 .31157E-01	.11289E+00 .76172E+00 .31121E-01	.10121E-01 -.84846E-02 -.36159E-04	.37448E+00 .136466E+03 .31162E-01	.605211E+00 .60451E+00 .31126E-01	.339951E-12 .383414E-06 .761599E-04
3	.10000E-01 .82449E+00 .21138E-01	.17813E+00 .56587E+00 .21202E-01	.14312E-01 .25872E-01 .63872E-04	.26034E+00 .184091E+03 .523014E-01	.277673E+00 .280311E+00 .523231E-01	.170716E-11 .383414E-06 .277126E-04
4	.15000E-01 .86493E+00 .11413E-01	.23765E+00 .50183E+00 .11562E-01	.17525E-01 .31798E-01 .14855E-03	.14169E+00 .196216E+03 .63715E-01	.179255E+00 .182396E+00 .638915E-01	.417615E-11 .383414E-06 .176270E-03
5	.20000E-01 .89357E+00 .72800E-02	.24895E+00 .44923E+00 .74346E-02	.20226E-01 .30672E-01 .15484E-03	.12471E+00 .20420E+03 .70995E-01	.111523E+00 .114496E+00 .71326E-01	.766526E-11 .383414E-06 .311113E-03
6	.24000E-01 .90347E+00 .36902E-02	.33875E+00 .41577E+00 .37379E-02	.22143E-01 .23966E-01 .10768E-03	.10985E+00 .208751E+03 .74685E-01	.722129E-11 .745864E-01 .751243E-01	.111990E-10 .383414E-06 .438797E-03
7	.28000E-01 .92161E+00 .22838E-02	.34243E+00 .38009E+00 .23737E-02	.23897E-01 .21092E-01 .49988E-04	.10393E+00 .22143E+03 .76949E-01	.421667E-01 .442654E-01 .74981E-01	.153061E-10 .383414E-06 .611121E-03
8	.32000E-01 .93133E+00 .11171E-02	.42559E+00 .36417E+00 .11994E-02	.25526E-01 .20097E-01 .82359E-04	.95202E-01 .215196E+03 .78086E-01	-.124054E-02 .71394E-03 .789436E-01	.202258E-10 .383414E-06 .672249E-03
9	.35000E-01 .93739E+00 .12990E-03	.51892E+00 .31558E+00 .25203E-03	.26663E-01 .17310E-01 .18261E-03	.89030E-01 .22041E+03 .716543E-01	-.300215E-01 .24226E-01 .743259E-01	.242832E-10 .783414E-06 .512777E-03
10	.42000E-01 .94889E+00 -.11140E-02	.94573E-03 -.24272E+00 -.24921E+00	.31877E-01 .19788E-01 .16004E-03	.10336E+00 .224041E+03 .739068E-01	-.677492E-01 .659460E-01 .743259E-01	.783414E-06 .935918E-3
11	.3591xE+00 .24292E+00 -.37747E-02					

****** CEBECI-KELLER BOUNDARY LAYER PROGRAM ******

CASE

N	X/C COS(ALPHA) CRLPF	S SIN(ALPHA) CRLVF	RO/C CRINT CRLDF	BETA UE CRAPF	CP PF CP CRAVF	SQUIG MJE CRADF
132	.991000E+00 .965221E+00 -.357441E-03	.100711E+02 -.261435E+00 -.163027E-03	.248145E-02 .939988E-01 .134414E-03	.21680AE+03 .204612E+03 .287445E-02	.249209E+00 .109174E+00 .620933E-02	.295396E-08 .383414E-06 .333680E-02
133	.993000E+00 .964498E+00 -.308250E-03	.109018E+02 -.260089E+00 -.130532E-03	.193687E-02 .836840E-01 .177719E-03	.421987E+03 .204953E+03 .256620E-02	.265945E+00 .107948E+00 .607840E-02	.295398E-08 .383414E-06 .351260E-02
134	.994000E+00 .964091E+00 -.133538E-03	.101022E+02 -.265570E+00 -.534461E-04	.166227E-02 .773023E-01 .804916E-04	.742579E+03 .205068E+03 .243266E-02	.275944E+00 .106945E+00 .602575E-02	.295398E-08 .383414E-06 .359309E-02
135	.996000E+00 .962917E+00 -.220795E-03	.101229E+02 -.269797E+00 -.811930E-04	.110759E-02 .624363E-01 .139602E-03	.186003E+04 .205389E+03 .221186E-02	.305506E+00 .104154E+00 .594656E-02	.295399E-08 .383414E-06 .373269E-02
136	.998000E+00 .969410E+00 -.145368E-03	.101437E+02 -.245447E+00 -.482778E-04	.540194E-03 .302570E-01 .970907E-04	.732793E+04 .206650E+03 .206659E-02	.323379E+00 .101875E+00 .589628E-02	.295399E-08 .383414E-06 .382979E-02
137	.100000E+01 .986884E+00 -.432418E-04	.101641E+02 -.164630E+00 -.154977E-04	.155015E-03 .567132E-02 .296922E-04	.926539E+05 .205929E+03 .202325E-02	.323379E+00 .993099E-01 .582273E-02	.295399E-08 .383414E-06 .365968E-02

CRAFA   CRAMA   CRAV23
.0038595   .0001018   .0008458

CASE
STATION NO.111

`****** CEBECI-KELLER BOUNDARY LAYER PROGRAM ******`
X/C = .900871

PROGRAM K90A

I	ETA	F	FD	FPP	Y	EPS+	UPLUS	VVEL/UE	X/C	R/C	R/RMAX	R-RO/RM	UX	UR	UTOT
1	0.0000	0.0000	0.00000	8.76550	0.00000	0.	0.000	-0.0000	.90087	.02212	.49424	0.0000	0.0000	0.0000	0.0000
3	.0107	.0005	.09275	8.47054	.00008	.384208E-01	2.974	.00001	.90087	.02213	.49441	.00017	.09031	-.01546	.09162
5	.0246	.0025	.19763	6.41056	.00018	.378645E+00	6.337	.00004	.90087	.02213	.49466	.00039	.19244	-.03291	.19524
7	.0427	.0070	.28698	3.66846	.00031	.142402E+01	9.202	.00010	.90088	.02215	.49492	.00068	.27946	-.04775	.28351
9	.0662	.0145	.35158	2.02083	.00048	.343062E+01	11.273	.00020	.90088	.02216	.49529	.00105	.34238	-.05842	.34732
11	.0967	.0260	.39887	1.17426	.00070	.668019E+01	12.790	.00036	.90088	.02219	.49578	.00153	.38845	-.06615	.39404
13	.1364	.0426	.43550	.72781	.00098	.114881E+02	13.964	.00057	.90089	.02221	.49641	.00216	.42416	-.07205	.43023
15	.1879	.0659	.46607	.48385	.00135	.179521E+02	14.944	.00087	.90089	.02225	.49722	.00298	.45397	-.07686	.46046
17	.2549	.0981	.49304	.35537	.00183	.266184E+02	15.803	.00128	.90090	.02230	.49828	.00403	.48030	-.08098	.48707
19	.3422	.1421	.51783	.24226	.00245	.376538E+02	16.624	.00182	.90091	.02236	.49965	.00541	.50453	-.08456	.51157
21	.4551	.2021	.54145	.18008	.00326	.516118E+02	17.361	.00255	.90093	.02244	.50143	.00718	.52765	-.08779	.53491
23	.6022	.2835	.56447	.13625	.00430	.693902E+02	18.100	.00352	.90094	.02254	.50372	.00948	.55023	-.09068	.55766
25	.7933	.3936	.58722	.10405	.00565	.923131E+02	18.829	.00481	.90097	.02267	.50670	.01245	.57260	-.09323	.58014
27	1.0417	.5424	.60985	.07979	.00739	.122078E+03	19.555	.00649	.90100	.02285	.51053	.01629	.59492	-.09536	.60251
29	1.3644	.7430	.63242	.06129	.00964	.160792E+03	20.278	.00862	.90103	.02307	.51547	.02123	.61726	-.09798	.62483
31	1.7839	1.0131	.65496	.04708	.01252	.211026E+03	21.001	.01132	.90108	.02335	.52183	.02758	.63968	-.09798	.64714
33	2.3291	1.3765	.67745	.03614	.01622	.275772E+03	21.722	.01513	.90114	.02372	.52997	.03573	.66218	-.09822	.66942
35	3.0376	1.8647	.69986	.02768	.02094	.354265E+03	22.441	.00966	.90122	.02418	.54037	.04612	.68476	-.09754	.69167
37	3.9584	2.5197	.72213	.02107	.02694	.463261E+03	23.155	.02525	.90133	.02477	.55359	.05935	.70737	-.09581	.71383
39	5.1550	3.3976	.74446	.01687	.03454	.561158E+03	23.871	.03203	.90145	.02552	.57012	.07608	.73025	-.09293	.73614
41	6.7001	4.5750	.76348	.01557	.04409	.578985E+03	24.673	.04020	.90162	.02645	.59135	.09711	.75597	-.08915	.76121
43	8.7312	6.1611	.79984	.01446	.05621	.578985E+03	25.646	.05001	.90182	.02764	.61762	.12337	.78716	-.08465	.79170
45	11.3577	8.3097	.83575	.01287	.07079	.578985E+03	26.798	.06158	.90210	.02910	.65017	.15593	.82406	-.07938	.82787
47	14.7712	11.2328	.87598	.01070	.08896	.578985E+03	28.048	.07542	.90237	.03089	.69019	.19595	.86544	-.07319	.86853
49	19.2207	15.2138	.91731	.00797	.11111	.578985E+03	29.413	.08932	.90275	.03307	.73937	.24473	.90811	-.06596	.91050
51	24.9726	20.6152	.95435	.00438	.13788	.578985E+03	30.601	.11048	.90320	.03571	.79793	.30368	.94665	-.05767	.94840
53	32.4651	27.8754	.98118	.00236	.16936	.578985E+03	31.461	.11815	.90374	.03887	.86860	.37435	.97511	-.04854	.97631
55	42.2003	37.5071	.99515	.00071	.20812	.578985E+03	31.909	.11024	.90438	.04263	.95265	.45840	.99073	-.03910	.99152
57	54.8509	50.1337	.99946	.00010	.25318	.578985E+03	32.047	.14638	.90514	.04704	1.05190	.55765	.99661	-.02995	.99706
59	71.3027	66.5767	1.00000	.00000	.30606	.578985E+03	32.064	.14929	.90604	.05228	1.16837	.67413	.99862	-.02136	.99885
61	92.6757	87.9446	1.00000	.00000	.36778	.578985E+03	32.065	.15759	.90708	.05837	1.30630	.81005	1.00001	-.02132	1.00009

	S	THETA	DELS	CF	CPL	CD(CALC)	CD(GRAN)
N	RX	RTHETA	H	DEL(GRAN)	CFA	CFA	CD(SQ-YN)
X/C	CHL MA	CFA MA	CFA MA	COCAL MA	COTCAL MA	CFA	COSV MA
						CDGR MA	
111	.914329E+01	.264138E-01	.341012E-01	.194526E-02	-.156447E-03	.109325E+00	.111929E+00
.90087	.114260E+08	.329022E+05	.129104E+01	.314204E+01	.109185E+00	.149269E-01	.111273E+00
.113044	-.125438E-05	.369038E-05	.287914E-02	.288284E-02	.274092E-02	.232386E-02	.293021E-02

COT(CALC)

CASE

****** CEBECI-KELLER BOUNDARY LAYER PROGRAM ******
OUTPUT SUMMARY

N / X/C / COT(CALC)	S / RX / CRL MA	THETA / RTHETA / CRA MA	DELS / H / CFA MA	CF / DEL(GRAN) / CDCAL MA	CPL / CFA / CDTCAL MA	CO(CALC) / CRA / CDGR MA	CO(GRAN) / CO(SQ-VN) / COSY MA	IMAX / FTAINF
2 / .005000 / .0065792	.112694E+00 / .900227E+05 / -.963517E-06	.967316E-04 / .771150E+02 / -.963517E-06	.226254E-03 / .233893E+01 / .509500E-04	.793704E-02 / .226090E-03 / .499965E-04	-.361598E-04 / .193216E-02 / .152723E-03	.189600E-02 / -.361593E-04 / .744878E-06	.282477E-04 / .356557E-04 / .962225E-06	45 / .113577E+02
3 / .010000 / .005987	.174136E+00 / .191621E+06 / .168428E-05	.124138E-03 / .129233E+03 / .730767E-06	.286588E-03 / .283549E+01 / .561055E-04	.449402E-02 / .286352E-03 / .568363E-04	.638724E-04 / .212677E-02 / .157878E-03	.215539E-02 / .277126E-04 / .453011E-05	.171794E-03 / .187119E-03 / .493423E-05	41 / .671013E+01
4 / .015000 / .006338	.237565E+00 / .272380E+06 / .391738E-05	.198372E-03 / .227444E+03 / .464415E-05	.341577E-03 / .172190E+01 / .653589E-04	.657791E-02 / .341283E-03 / .700070E-04	.148557E-03 / .247685E-02 / .167131E-03	.265465E-02 / .176627E-03 / .127033E-04	.481743E-03 / .495054E-03 / .130543E-04	47 / .147712E+02
5 / .020000 / .006847	.294395E+00 / .351275E+06 / .403313E-05	.303342E-03 / .361951E+03 / .871288E-05	.473385E-03 / .156060E+01 / .787754E-04	.611497E-02 / .472081E-03 / .875066E-04	.154843E-03 / .298737E-02 / .180548E-03	.331844E-02 / .331113E-03 / .261377E-04	.991208E-03 / .100396E-02 / .264738E-04	50 / .219014E+02
6 / .024000 / .007294	.338752E+00 / .413208E+06 / .283957E-05	.373600E-03 / .457151E+03 / .115709E-04	.573032E-03 / .153381E+01 / .905549E-04	.556907E-02 / .572359E-03 / .103126E-03	.107684E-03 / .343438E-02 / .192327E-03	.387287E-02 / .438797E-03 / .380949E-04	.144466E-02 / .165591E-02 / .383916E-04	47 / .147712E+02
7 / .028000 / .007762	.382430E+00 / .470472E+06 / .237294E-05	.436698E-03 / .543338E+03 / .139338E-04	.658782E-03 / .156055E+01 / .102306E-03	.526996E-02 / .657947E-03 / .116648E-03	.499808E-02 / .390245E-02 / .204678E-03	.443121E-02 / .528785E-03 / .508447E-04	.192816E-02 / .193651E-02 / .510647E-04	49 / .192074E+02
8 / .032000 / .008254	.425596E+00 / .551570E+06 / .217116E-05	.494326E-03 / .621996E+03 / .161149E-04	.736166E-03 / .149623E+01 / .115880E-03	.501898E-02 / .735180E-03 / .131995E-03	.823359E-04 / .439448E-02 / .217653E-03	.500563E-02 / .611121E-03 / .645735E-04	.244878E-02 / .245253E-02 / .646720E-04	50 / .219014E+02
9 / .035000 / .008639	.457700E+00 / .581157E+06 / .155919E-05	.536735E-03 / .680337E+03 / .176741E-04	.792723E-03 / .147693E+01 / .126038E-03	.492280E-02 / .791621E-03 / .143712E-03	.591287E-04 / .477969E-02 / .227810E-03	.544993E-02 / .572293E-03 / .752926E-04	.285511E-02 / .245529E-02 / .752926E-04	52 / .284738E+02
10 / .042000 / .009583	.531892E+00 / .683891E+06 / .332217E-05	.630196E-03 / .810287E+03 / .215663E-04	.919762E-03 / .145943E+01 / .159027E-03	.461722E-02 / .918388E-03 / .171984E-03	.128261E-03 / .572356E-02 / .262720E-03	.652207E-02 / .795510E-03 / .101115E-03	.384357E-02 / .383336E-02 / .101110E-03	52 / .284738E+02
11 / .050000 / .010733	.615724E+00 / .806070E+06 / .360756E-05	.724412E-03 / .943582E+03 / .246639E-04	.104479E-02 / .144226E+01 / .181406E-03	.434607E-02 / .103314E-02 / .205070E-03	.136008E-03 / .647378E-02 / .283178E-03	.781470E-02 / .335514E-01 / .134461E-03	.509913E-02 / .507220E-02 / .137721E-03	51 / .249725E+02
12 / .055000 / .011254	.667709E+00 / .823380E+06 / .221762E-05	.781649E-03 / .103235E+04 / .268415E-04	.112110E-02 / .143428E+01 / .201586E-03	.434600E-02 / .119227E-02 / .244677E-03	.849600E-04 / .103584E-01 /	.866605E-02 / .101943E-02 / .156471E-03	.589377E-02 / .549937E-02 / .154421E-03	53 / .324651E+02

CASE

****** CEBECI-KELLER BOUNDARY LAYER PROGRAM ******

PROGRAM K90A

N X/C COT(CALC)	S RX CRL MA	THETA RTHETA CFA MA	DELS H CFA MA	CF DEL(GRAN) COCAL MA	CRL CFA COTCAL MA	CO(CALC) CFA COGR MA	CO(GRAN) COISQ-VN) COSY MA	IAX ETAINMF
134 .99000 .114901	.10102ZE+02 .121052E+08 .212253E-05	-.49777E+00 .491028E+06 .947431E-04	.52659E+00 .12849E+01 .292812E-02	.118875E-02 .116607E+00 .302287E-02	.804918E-04 .111042E+00 .30294E-02	.114635E+00 .359309E-02 .298550E-02	.113218E+00 .113954E+02 .30036CE-02	61 .92675E+02
135 .99000 .114904	.10123E+02 .12149E+08 .368122E-05	.611805E+00 .734658E+06 .984233E-04	.78393E+00 .12613E+01 .292819E-02	.100008E-02 .132881E+33 .302662E-02	.139602E-02 .111145E+00 .302997E-02	.147777E+00 .373263E-02 .298564E-02	.113223E+00 .113842E+00 .30030ZE-02	61 .92675E+02
136 .99000 .114906	.10143E+02 .121895E+08 .256023E-05	.12466E+02 .149411E+07 .100930E-03	.15913E+01 .127650E+01 .292823E-02	.64189E-03 .12772CE+00 .302922E-02	.970907E-04 .111146E+00 .30300CE-02	.114875E+00 .382979E-02 .298018E-02	.113016E+00 .113647E+00 .296683E-02	61 .92675E+02

COC V2/3 .025180	COGR V2/3 .024766	COSY V2/3 .024934	COC MA .003030	COGR MA .002980	COSY MA .002997	COC FA .114906	COGR FA .113016	COSY FA .113647

N	(X/C)OLO	RO	DELS	DELGR	(RC+DELG)/C	(X/C)NEW	(RC+DG*COS)/C
1	G.JOCCOJO	.0016000	C.00000000	0.00000000	0.0001000	0.0000000	0.0001000
2	.JO5CCJJO	.10121734	.JOO22625	.JOO22625	.01014434	.00498278	.01013638
3	.0100000	.14312855	.00028659	.00028635	.01434434	.00498380	.01013639
4	.0150000	.17525031	.00034158	.00034129	.01755916	.01498287	.01433646
5	.0200000	.20226215	.00047338	.JC047289	.02027350	.01997877	.01755455
6	.0240000	.22143332	.JC057303	.0057236	.02220C57	.C2239762.	.02026847
7	.0280000	.23897417	.00065878	.00065795	.02346361	.02797447	.02219539
8	.0320000	.25520416	.JC073617	.JC073518	.0255393	.03197323	.02395845
9	.0350000	.2666360S	.00079272	.00079162	.02674277	.03497243	.0255889
10	.0420000	.29122153	.00031976	.00091839	.02921399	.04197102	.02673781
11	.35000000	.31627671	.00104479	.00104314	.0317319A	.0497049	.02920930
12	.05000000	.33050493	.00112110	.00112110	.03316242	.0497C4C	.03172772
13	.06000000	.34373112	.J0113888	.00119687	.0344928C	.C5997C44	.0311584 3
14	.06500000	.35601605	.00127644	.JO127422	.03572873	.0647087	.0344090 9
15	.0700000	.36739418	.J2135294	.JC135051	.0368747	.C693711 5	.03572531
16	.07500000	.37760795	.00143037	.00142773	.03793357	.07437174	.0368713 5
17	.0ACC000	.3875804	.00150472	.00150582	.03890067	.0793725A	.03793075
18	.08500000	.3b43471	.JO15A079	.00158567	.03940206	.CA497357	.03890615

#							
118	.9620000	.0976297	.09046634	.06769439	.01656574	.96354595	.01638686
119	.9670000	.0860712	.10411832	.07356086	.01596480	.96871996	.01576090
120	.9700000	.07881885	.11432134	.07740093	.01562198	.97183531	.01540124
121	.9720000	.07351305	.12216703	.08006397	.01539770	.97391624	.01516500
122	.9740000	.06895859	.13117965	.08286561	.01518242	.97630181	.01493699
123	.9750000	.06646298	.13617000	.08430286	.01507658	.97734600	.01482454
124	.9760000	.06395505	.14142563	.08571713	.01496722	.97808399	.01470852
125	.9780000	.05890203	.15337467	.08867653	.01475786	.98018223	.01448515
126	.9790000	.05635682	.16017546	.09021290	.01465697	.98123030	.01437693
127	.9810000	.05122874	.17568682	.09334093	.01445697	.98332902	.01416173
128	.9830000	.04655000	.19486558	.09666963	.01427196	.98543441	.01396042
129	.9850000	.04082005	.21909652	.10018686	.01410069	.98754636	.01377170
130	.9870000	.03553819	.25065425	.10388819	.01394264	.98966501	.01359500
131	.9890000	.03020350	.29356161	.10778811	.01379916	.99179105	.01343154
132	.9910000	.02481453	.35556614	.11192559	.01367401	.99392612	.01328475
133	.9930000	.01936465	.45327171	.11632991	.01356986	.99597215	.01315686
134	.9940000	.01662269	.52655945	.11860723	.01352299	.99714986	.01309709
135	.9960000	.01107589	.78333479	.12328117	.01343571	.99932609	.01297854
136	.9980000	.00540194	1.59139465	.12771985	.01331218	1.00113484	.01292149

U TAIL	X TAIL	GAMA TAIL		H TAIL	REF LEN
.9485932	1.0000000	.0000000	.0000682	1.2765018	10.0000000

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DIMENSIONLESS

X	MOM AREA	FORM FAC M	DISP AREA	EFF THICK	U/UINF	CP
1.000000	.0000682	1.275018	.0000870	.0133924	.9449032	.0996309
1.020000	.0000679	1.275144	.0000865	.0131560	.9503160	.0994615
1.040000	.0000675	1.274592	.0000860	.0131183	.9517406	.0941498
1.060000	.0000672	1.273932	.0000855	.0130796	.9531811	.0914457
1.080000	.0000669	1.272047	.0000850	.0130412	.9546116	.0887167
1.100000	.0000665	1.270587	.0000842	.0129974	.9562425	.0856002
1.120000	.0000657	1.270859	.0000832	.0129033	.9597455	.0788886
1.140000	.0000646	1.263522	.0000816	.0127730	.9645026	.0695805
1.160000	.0000631	1.259677	.0000792	.0125834	.9715329	.0561238
1.180000	.0000620	1.246598	.0000773	.0124360	.9767854	.0458903
1.200000	.0000613	1.240240	.0000760	.0123267	.9806164	.0383915
1.250000	.0000605	1.237840	.0000746	.0122127	.9844254	.0309066
1.300000	.0000599	1.226817	.0000734	.0121149	.9875203	.0248036
1.350000	.0000594	1.217750	.0000723	.0122238	.9902212	.0194617
1.400000	.0000590	1.211553	.0000715	.0119566	.9920474	.0158620
1.450000	.0000587	1.204992	.0000706	.0118822	.9939668	.0121748
1.500000	.0000583	1.192032	.0000695	.0117929	.9958117	.0083591
1.600000	.0000581	1.181022	.0000688	.0117281	.9969668	.0065572
1.700000	.0000579	1.176847	.0000682	.0116783	.9977093	.0045761
1.800000	.0000579	1.706679	.0000677	.0116382	.9982142	.0035683
2.000000	.0000578	1.653628	.0000673	.0116053	.9985681	.0028617
2.400000	.0000578	1.563599	.0000667	.0115519	.9990321	.0019344
3.000000	.0000577	1.149008	.0000662	.0115101	.9993090	.0013815
4.500000	.0000576	1.402273	.0000657	.0114617	.9995483	.0009033
6.000000	.0000576	1.291130	.0000650	.0114022	.9997466	.0005068
10.000000	.0000575	1.162923	.0000642	.0113349	.9998781	.0002438
20.000000	.0000575	1.026802	.0000634	.0112644	.9999490	.0001020
30.000000	.0000575	1.031922	.0000629	.0112154	.9999741	.0000629
	.0000575	1.085003	.0000623	.0111653	.9999880	.0000240
	.0000575	1.022219	.0000617	.0110669	.9999957	.0000087
	.0000575	1.065422	.0000612	.0110670	.9999980	.0000040
	.0000575	1.056055A	.0000608	.011228	.9999993	.0000015
	.0000575	1.068248	.0000602	.0109745	.9999998	.0000001
	.0000575	1.037120	.0000597	.0109245	1.0000000	.0000000
	.0000575	1.004013A	.0000578	.0107478	1.0000000	.0000000

DIMENSIONAL

X	MOM AREA	DISP AREA	EFF THICK
10.000000	.0066173	.0083019	.1319236
10.020000	.0067853	.0086542	.1315600
10.040000	.0067525	.0086045	.1311828
10.060000	.0067192	.0085539	.1307961
10.080000	.0066863	.0085037	.1304122
10.100000	.0066491	.0084467	.1299745
10.140000	.0065701	.0083248	.1290335
10.200000	.0064631	.0081574	.1277295
10.300000	.0063137	.0079171	.1258363
10.400000	.0062040	.0077338	.1243686
10.500000	.0061257	.0075974	.1232668
10.640000	.0060493	.0074575	.1221271
10.820000	.0059843	.0073386	.1211493
11.000000	.0059360	.0072286	.1202383
11.200000	.0059008	.0071680	.1195656
11.500000	.0058657	.0077596	.1184223
12.000000	.0058297	.0069536	.1179292
12.500000	.0058081	.0068774	.1172812
13.000000	.0057944	.0068192	.1167833
13.500000	.0057851	.0067724	.1163825
14.000000	.0057746	.0067342	.1160533
15.000000	.0057701	.0066724	.1155193
16.000000	.0057651	.0066241	.1151012
17.500000	.0057608	.0065686	.1146174
20.000000	.0057572	.0065005	.1140219
24.000000	.0057548	.0064241	.1133495
30.000000	.0057535	.0063463	.1126438
36.000000	.0057531	.0062892	.1121538
45.000000	.0057528	.0062332	.1116531
60.000000	.0057527	.0061681	.1111687
75.000000	.0057526	.0061240	.1106703
100.000000	.0057526	.0060751	.1102281
140.000000	.0057526	.0060220	.1097452
200.000000	.0057526	.0059673	.1092454
300.000000	.0057526	.0057757	.1074776

SOLUTIONS FOR COEFFICIENTS OF FAIRING POLYNOMIAL

-.901655E+03
.401281E+04
-.743E0E+04
-.338E07E+04
.767256E+03

DIMENSIONLESS

X	EFF THICK
.950000	.0151448
.957000	.0172002
.962000	.0165602
.967000	.0159613
.970000	.0156248
.972000	.0154108
.974000	.0152052
.975000	.0151058
.976000	.0150085
.978000	.0148205
.978000	.0147249
.981000	.0145554
.983000	.0143993

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.9850000	.0142333
.9870000	.0140855
.9890000	.0139465
.9910008	.0138160
.9930000	.0136939
.9940000	.0136359
.9960000	.0135258
.9980000	.0134235
1.0000000	.0133286
1.0020000	.0132408
1.0040000	.0131598
1.0060000	.0130851
1.0080000	.0130165
1.0100000	.0129535
1.0140000	.0128429
1.0200000	.0127096
1.0300000	.0125489
1.0400000	.0124299
1.0500000	.0123267

DIMENSIONLESS	
X	EFF THICK
.9500000	.0181448
.9570000	.0172002
.9620000	.0165602
.9670000	.0159613
.9700000	.0156246
.9720000	.0154108
.9740000	.0152052
.9750000	.0151058
.9760000	.0150085
.9780000	.0148205
.9790000	.0147299
.9810000	.0145554
.9830000	.0143859
.9850000	.0142333
.9870000	.0140855
.9890000	.0139465
.9910000	.0138160
.9930000	.0138939
.9940000	.0136359
.9960000	.0135258
.9980000	.0134235
1.0000000	.0133286
1.0020000	.0132408
1.0040000	.0131598
1.0060000	.0130851
1.0080000	.0130165
1.0100000	.0129535
1.0140000	.0128429
1.0200000	.0127096
1.0300000	.0125489
1.0400000	.0124299
1.0500000	.0123267
1.0640000	.0122127
1.0800000	.0121149
1.1000000	.0120238
1.1200000	.0119566
1.1500000	.0118822
1.2000000	.0117929
1.2500000	.0117281
1.3000000	.0116783
1.3500000	.0116382
1.4000000	.0116053
1.5000000	.0115519

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1.6000000      .0115101
1.7500000      .0114617
2.0000000      .0114022
2.4000000      .0113349
3.0000000      .0112644
3.6000000      .0112154
4.5000000      .0111653
6.0000000      .0111069
7.5000000      .0110670
10.0000000     .0110228
14.0000000     .0109745
20.0000000     .0109245
30.0000000     .0107478
```

TABLE 3

COMPARISON OF RESULTS AT TAIL FOR TWO
LOCATIONS OF TRANSITION

	Virtual Origin $X/RL = 0.015$	Trip Location $X/RL = 0.05$
CFA WA	0.002928	0.002896
CRA WA	0.000102	0.000104
CDC WA	0.003030	0.003000
DELS	1.5914	1.5734
H TAIL	1.2765	1.2768
U TAIL	0.9490	0.9489

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